

THE FOOD AND FEEDING OF WINTER WHITING (*SILLAGO MACULATA* QUOY AND GAIMARD) IN MORETON BAY

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Synopsis

A description of the mouth structure and alimentary canal of *Sillago maculata* is given to indicate minor adaptations associated with a bottom feeding carnivore. Adult whiting, those longer than 10 cm., were found to consume polychaete worms mainly, but also a variety of crustaceans, echinoderms, and small fish, as well as pelecypod molluscs, and *Glossobalanus*.

The diet of juvenile whiting, which frequent shallower waters, was found to consist largely of mysidaceans and amphipods, and smaller quantities of other crustaceans, pycnogonids, polychaetes and gastropods.

In adults there is a change of diet with size. Only fish longer than 15 cm. were found to consume significant quantities of molluscs; only fish longer than 16.5 cm. consumed *Glossobalanus*; and only fish longer than 17 cm. ate brittle stars. No plant material was found in any whiting.

INTRODUCTION

Sillago maculata is a bottom feeder and forms part of the benthic nekton in Moreton Bay. It is a carnivorous fish, although fishermen sometimes assert that the fish feed on weed during the spawning season. For most of the year adult whiting inhabit parts of the bay which possess a muddy substrate. Some time is apparently spent in sandy areas (Roughley, 1916). However, no specimens were found in sandy parts of Moreton Bay in the course of this study.

The following description of the alimentary system of this species indicates the minor adaptations correlated with feeding behaviour.

(1) *Dentition*. Small villiform teeth are present on both jaws. Fine vomerine teeth are also present. Cardiform pharyngeal teeth occur as firm pads, a large median pad on the dorsal and two smaller pads on the medio-ventral surface of the pharynx, which leads to a short oesophagus.

(2) *Jaws*. The jaws are modified to enable the gape of the mouth to be directed obliquely downwards. This is accomplished by a membrane which allows protrusion of the upper jaw over the lower. A cartilaginous spine attached to the premaxilla provides rigidity for the membrane.

(3) *Alimentary canal*. The digestive tract is typically carnivorous in proportions (Al-Hussaini, 1949). An elongate caeciform stomach is present; there are four pyloric caeca, and a short intestine follows. A nematode parasite frequently invades the intestine, and, less commonly, the stomach.

METHODS AND MATERIAL

Adult whiting examined for stomach contents were captured by trawl between Mud and St. Helena islands in Moreton Bay in March, May, June and September, 1966. The sampling area was typical of a large part of the bay, having a substrate of deep, soft, sandy mud. Depth ranged from two to six fathoms.

No juvenile whiting were obtained in this sampling area. Juvenile specimens were captured in water less than one fathom deep by bait net near the mouth of the Brisbane River in June and November, 1966, only.

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After capture, the fish were immediately placed in 10% formalin. Altogether, 433 whiting, including 42 juveniles, were examined for stomach contents. The size of juvenile fish ranged from 2.8 cm. to 9.6 cm., and the largest fish examined were 21 cm. Lengths of fish were caudal fork measurements (l.c.f.), that is the distance from the tip of the snout to the fork in the caudal fin.

In this study, only the presence or absence of each type of food organism was recorded. More sophisticated analyses, such as volumetric or gravimetric techniques (see review by Hynes, 1950), were precluded by the frequently disintegrated condition of the food in the stomachs. In many cases, food organisms were recognizable by their hardened portions only, such as skulls or other bones in fishes, parapodial chaetae in polychaetes, and various appendages or exoskeleton in the crustaceans. Stomachs in which no recognizable food organisms were found were either empty or contained small amounts of fluid mucus. Both these conditions were recorded as empty stomachs. By summation of the whole sample, results were converted to percentage occurrence of each item in the stomachs.

No significant variation with time was noted in the sampling period. Consequently, analysis of the data has been confined to variations in the diet with size of fish.

TABLE 1
Food Organisms Found in Stomachs of Winter Whiting in Moreton Bay

Classification	Genera or species
Phylum Annelida	
Class Polychaeta	Several species
Phylum Mollusca	
Class Pelecypoda	Several species
Class Gastropoda	One species
Phylum Arthropoda	
Class Pycnogonida	One species
Class Crustacea	
(a) Cirripedia	<i>Lepas</i> sp.
(b) Copepoda (Cyclopoida)	One species
(c) Ostracoda	One species
(d) Malacostraca (Amphipoda)	
Fam. Gammaridae	Several species
Fam. Caprellidae	Several species
Malacostraca (Stomatopoda)	<i>Squilla</i> spp.
" (Mysidacea)	<i>Heteromysis</i> sp.
" (Decapoda)	<i>Penaeus</i> , <i>Metapenaeus</i> , <i>Thenus</i> , several species
Phylum Echinodermata	
Class Ophiuroidea	One species
Class Holothuroidea	One species
Phylum Chordata	
Sub-phylum Hemichordata	<i>Glossobalanus</i> sp.
Sub-phylum Vertebrata	
Class Osteichthyes	Several species, including <i>Hyperlophus translucidus</i> McCulloch



RESULTS

A list of all identified genera or groups of food organisms found in the stomachs of *S. maculata* is recorded in Table 1. Of the 433 fish examined, 114 had empty stomachs.

Initially, the whiting were divided into two broad categories according to gonad condition, juvenile and adult, the latter class including all fish longer than 10 cm.

The diet of juvenile whiting was found to consist largely of small crustaceans, the largest being about 3 mm. long. The most prominent were found to be mysideans. Amphipods were second in order of abundance, and species of Gammaridae and Caprellidae were obtained. The mysids and amphipods were the most commonly occurring organisms in the stomachs and when present were usually in large quantity.

The remainder of organisms eaten by juveniles occurred infrequently and in small numbers. They include species of Polychaeta, Pycnogonida, Ostracoda, Copepoda, and Mollusca. Interestingly, only two of the juvenile whiting analysed had empty stomachs when examined. The frequency of occurrence of each food organism in the 42 fish examined is shown below in Table 2.

TABLE 2
*Frequency of Occurrence of Food Organisms in the Stomachs of
42 Juvenile Whiting*

Food organisms	Number of stomachs containing food organism	Frequency of occurrence in stomachs containing food (percentage)
Mysidacea	24	60
Amphipoda	12	30
Polychaeta	6	15
Pycnogonida	2	5
Ostracoda	2	5
Copepoda	1	2.5
Gastropoda	1	2.5
Empty stomachs ..	2	5

TABLE 3
*Frequency of Occurrence of Food Organisms in the Stomachs of
391 Adult Whiting*

Food organism	Number of stomachs containing food organism	Frequency of Occurrence in stomachs containing food (percentage)
Polychaeta	173	62
Pelecypoda	54	19.5
Ophiuroidea	29	10.5
Holothuroidea	3	1
<i>Glossobalanus</i>	17	6
Brachyura	41	15
Penaeidae	15	5.5
<i>Squilla</i>	8	3
Other Crustacea	48	17
Fish	15	5.5
Empty stomachs ..	112	—

Polychaete worms are by far the most commonly occurring food organism in the stomachs of adult whiting. Bivalve molluscs and crustaceans, especially crabs, comprise most of the remaining portion of the diet. Other crustaceans eaten in small numbers include prawns, mantis shrimps, barnacles, and the shovel nose lobster. Acorn worms (*Glossobalanus*), small fish, sea cucumbers,

and brittle stars are also minor dietary items. One specimen only of Gastropoda was found. The frequency of occurrence of each food organism in adult whiting is shown in Table 3. "Other Crustacea" includes fragments of organisms not further recognizable.

Since there appeared to be some dietary differences between adult whiting of different sizes, they were divided into two arbitrary classes, small (10.1–15.5 cm.) and large (15.6–21.0 cm.), which were compared by "t" test for quantitative differences in dietary organisms. The tests revealed that at the 5% level of significance small adult whiting consumed relatively fewer molluscs, acorn worms and brittle stars, but more crustaceans other than those *identifiable* as crabs, prawns, or mantis shrimps.

TABLE 4
Frequency of Occurrence of Specified Food Organisms in Whiting of Various Size Groups

Size range (cm.)	Number of Fish	Empty stomachs (Percentage)	Brittle stars (Percentage)	Crabs (Percentage)	Molluscs (Percentage)	Polychaetes (Percentage)
10.1–10.5 ..	10	0	0	20	0	40
10.6–11.0 ..	6	0	0	17	17	50
11.1–11.5 ..	14	0	0	0	7	29
11.6–12.0 ..	12	0	0	0	8	42
12.1–12.5 ..	9	56	0	0	0	50
12.6–13.0 ..	7	29	0	20	0	60
13.1–13.5 ..	12	25	0	0	0	78
13.6–14.0 ..	19	16	0	13	0	50
14.1–14.5 ..	24	0	0	9	5	45
14.6–15.0 ..	30	20	0	4	4	46
15.1–15.5 ..	35	8	0	13	13	53
15.6–16.0 ..	17	23	0	8	22	54
16.1–16.5 ..	14	28	0	0	20	60
16.6–17.0 ..	16	69	0	20	0	40
17.1–17.5 ..	15	27	18	9	19	45
17.6–18.0 ..	25	24	5	0	21	58
18.1–18.5 ..	37	24	29	14	19	29
18.6–19.0 ..	37	27	19	14	19	33
19.1–19.5 ..	23	35	13	20	7	47
19.6–20.0 ..	16	69	0	0	0	80
20.1–20.5 ..	13	8	17	25	25	25
20.6–21.0 ..	6	17	20	20	0	40

A more detailed division of the adult whiting into 0.5 cm. size groups showed that acorn worms were found in fish longer than 16.5 cm. only, and brittle stars in fish longer than 17.0 cm. Molluscs became "regular" food items only in whiting longer than about 15 cm. The occurrence of "other Crustacea" became insignificant in fish longer than 16 cm. Table 4 shows the percentages of whiting in the various size groups whose stomachs contained one or more food items.

DISCUSSION

The dietary differences between juvenile and adult whiting are significant with regard to feeding behaviour. The minute crustaceans and pycnogonids which comprise the bulk of the diet of juvenile whiting are planktonic or cling to weeds. Bottom-living fauna, the small polychaete worms, are minor food items of juvenile fish. Thus, juvenile whiting are basically not bottom feeders. On the other hand, the adult whiting diet consists mainly of comparatively large benthic organisms, especially polychaetes and pelecypods. The change of diet apparently occurs during the movement of juvenile whiting from the shallows into deeper waters of the bay.

The selection by larger adult whiting of acorn worms, brittle stars and molluscs is difficult to explain. The species of brittle star consumed is one of the most commonly occurring invertebrate organisms in Moreton Bay, although apparently undescribed (Stephenson, personal communication). Pelecypoda possess hard shells which may deter smaller fish from eating them. The pharyngeal teeth, by which hard particles such as shells are broken up, probably strengthen with age.

The finding of less identifiable remains of crustaceans ("other Crustacea") in large fish may also be correlated with a hardening or strengthening of teeth and jaws, such that less time is required to grind the food to a size which allows efficient digestion. If so, the frequency of occurrence of recognizable portions of the various crustacean food organisms may be correspondingly less. On the other hand, larger fish may simply tend to ignore most crustaceans, except crabs, as food.

TABLE 4—Continued

Size range (cm.)	Number of Fish	Acorn Worms (Percentage)	Prawns (Percentage)	Mantis Shrimps (Percentage)	Other Crustacea (Percentage)	Fish (Percentage)
10.1-10.5 ..	10	0	0	0	40	0
10.6-11.0 ..	6	0	0	0	16	0
11.1-11.5 ..	14	0	0	0	35	29
11.6-12.0 ..	12	0	17	8	17	8
12.1-12.5 ..	9	0	0	0	50	0
12.6-13.0 ..	7	0	0	0	20	0
13.1-13.5 ..	12	0	0	0	22	0
13.6-14.0 ..	19	0	18	0	19	0
14.1-14.5 ..	24	0	5	9	27	0
14.6-15.0 ..	30	0	4	8	26	8
15.1-15.5 ..	35	0	0	3	12	6
15.6-16.0 ..	17	0	8	0	8	0
16.1-16.5 ..	14	0	20	0	0	0
16.6-17.0 ..	16	20	0	0	20	0
17.1-17.5 ..	15	0	9	0	0	0
17.6-18.0 ..	25	5	5	0	6	0
18.1-18.5 ..	37	3	3	0	0	3
18.6-19.0 ..	37	3	4	4	0	4
19.1-19.5 ..	23	7	0	0	6	0
19.6-20.0 ..	16	0	20	0	0	0
20.1-20.5 ..	13	0	0	0	0	8
20.6-21.0 ..	6	0	0	0	20	0

The problem of relative importance of the various food organisms of *S. maculata* is pertinent to this study. Since volumetric and gravimetric methods were not applicable, the biomass of each item cannot be determined. In adult whiting the most frequently occurring food organisms, polychaetes, were also the largest, so that there is no question as to the main source of their metabolic requirements. The problem is significant in juvenile whiting, however. Food organisms of juveniles fall into two classes according to size: the minute planktonic forms and the somewhat larger polychaetes. The numbers of the former, when they occurred in the stomachs of the juvenile whiting, usually exceeded polychaetes at least sixfold, one worm fragment only being normally found in the stomach of a single juvenile fish. On the other hand, the polychaete pieces eaten were larger than the other food organisms, and thus polychaetes may approximate, or even exceed, the biomass of other foods eaten by the juvenile whiting.

Food preferences in fish are well known (Blegvad, 1930; Ivlev, 1961), and it is apparent that some form of food selection is exhibited by whiting.

Knowledge of the relative abundances of the benthic fauna in the whiting feeding grounds is required to ascertain the extent of this selection. It is hoped that the degree of preferences for different organisms by whiting in Moreton Bay can be established in the future, since Stephenson (personal communication) is currently investigating the abundance and distribution of benthic organisms there.

TAINTING

Fishermen frequently claim that adult whiting eat an iodine-rich weed during the spawning season. The basis of this claim is a characteristic odour, reminiscent of iodine, possessed by some mature specimens. Its origin was not discovered in the present study, and although some fish were found to possess this odour, none contained plant food of any type in their stomachs or intestines. The occurrence of the taint is of no commercial importance and it has not been sufficiently widespread to warrant investigation by fisheries authorities.

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